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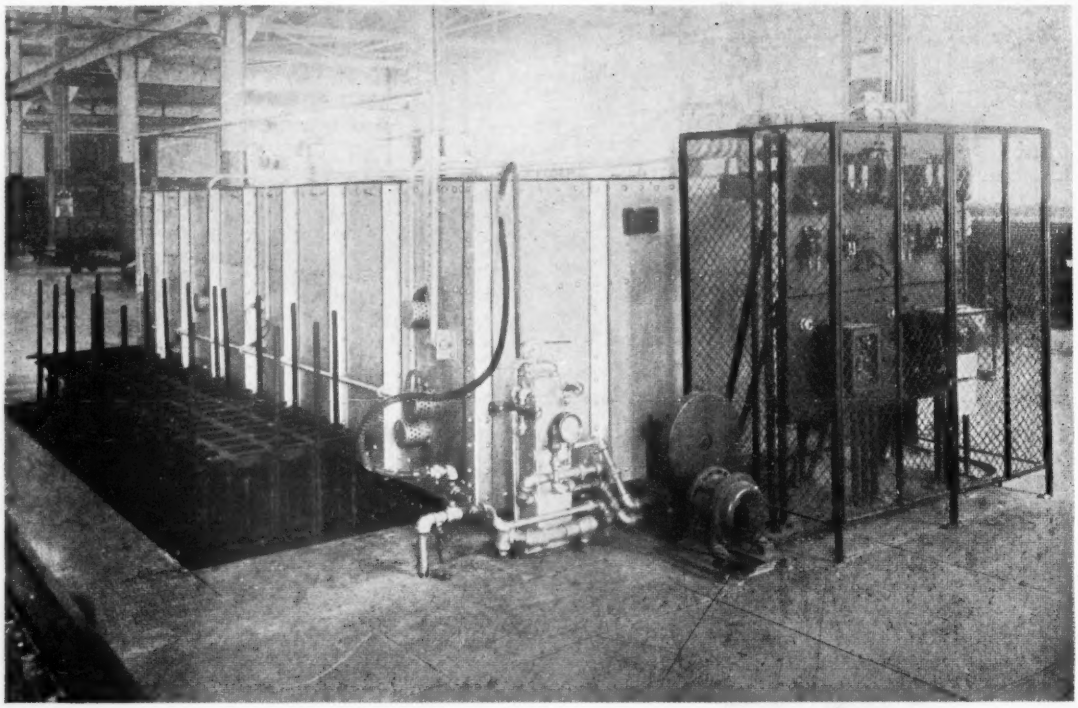

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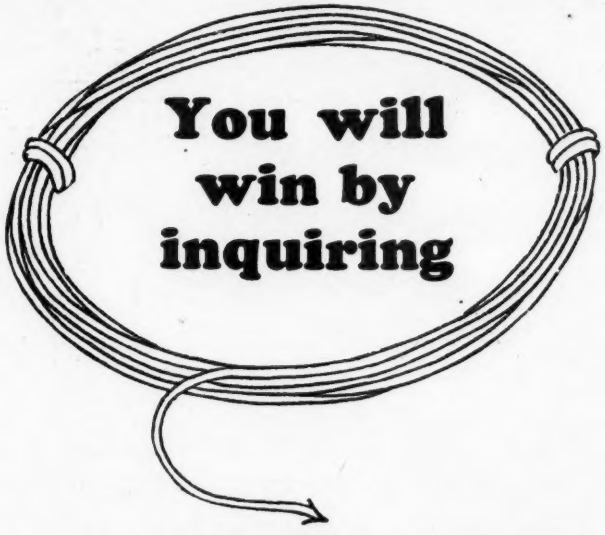


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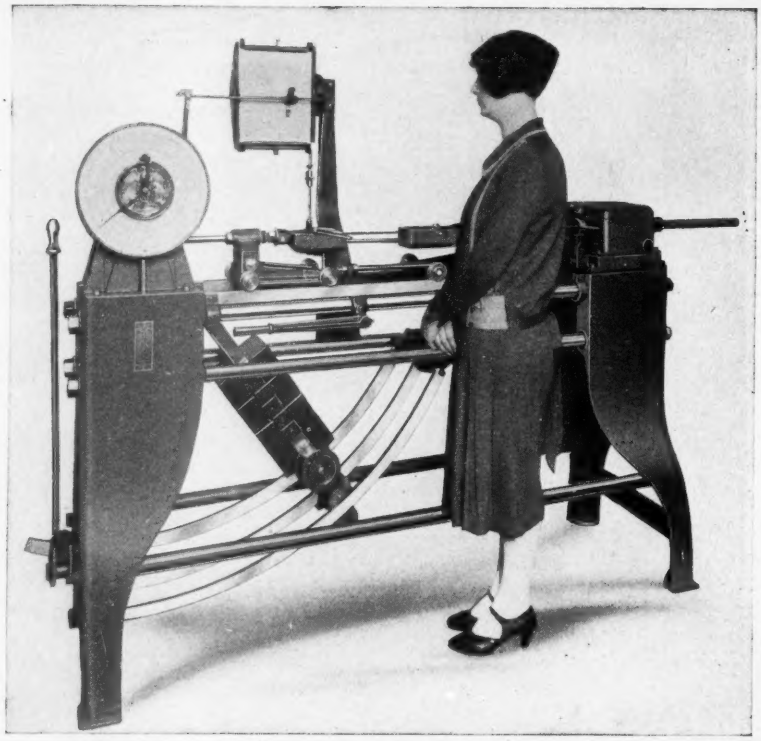

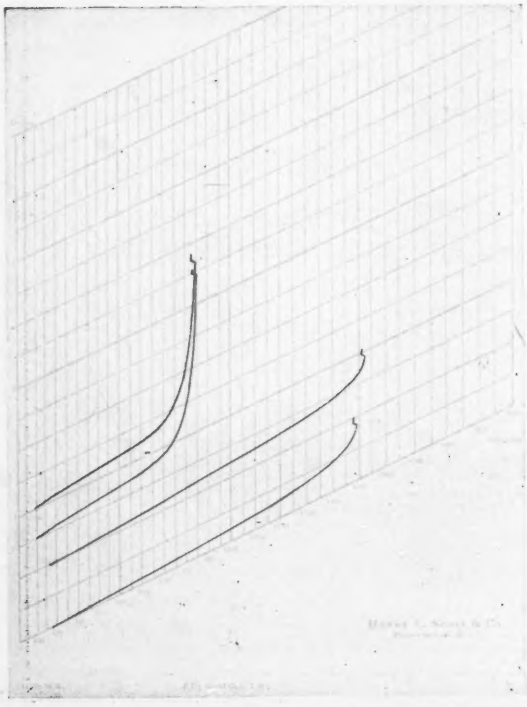

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* * *

We are pleased to be able to call the attention of our readers to the article on hairsprings published in the present issue. This is the second of a series of articles appearing in Wire & Wire Products dealing with British practice in various departments of the industry.

*The Publishers.*


# WIRE & WIRE PRODUCTS

A monthly publication devoted to wire drawing and wire forming

Vol. 2 April, 1927 No. 4


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WIRE & WIRE PRODUCTS

Vol. 2 APRIL, 1927 No. 4

# Recent Investigations on the Manufacture and Properties of Hair Springs*

*By H Moore, O. B. Sc. and S. Beckinsale, B. Sc. A. I. C.,*
*Research Department, Woolwich, England*

SYNOPSIS

*The function and essential properties of hairsprings and control springs are discussed. The respective merits and disadvantages of steels, ferrous alloys (e. g. Elinvar), and non-ferrous metals and alloys as hairspring materials are indicated. To raise the elastic limit to the required degree, hardening by heat-treatment or by cold-working is necessary, but all hardening operations are liable to produce a state of imperfect elasticity detrimental to the spring. The use of low-temparature heat-treatments to restore elasticity after cold-working (drawing, rolling, and the coiling of the spring) is described. Steel hairsprings are subject to corrosion, but Elinvar is highly resistant. Some details of the manufacture of phosphor-bronze and other hairsprings are given, and the selection of material for hairsprings required to have a low electrical resistance is discussed.*

THE function of hairsprings and control springs is to control the rate of oscillation of a balance (as in watches and chronometers), or the deflection of a suspended part submitted to a torque (as in galvanometers, &c.). The form, dimensions, and modulus of elasticity determine the strength of the spring. In addition, the qualities required in a hairspring are perfect elasticity throughout the maximum range of deflection applied, permanence and invariability of elastic properties, and of form and dimensions when unconstrained or under a given torque, and resistance to corrosion. Thus the effect of processes of manufacture and assembly on the elastic properties of hairsprings is of great importance.

Some confusion as to the properties required is occasionally encountered. Cases have indeed come to notice in which, when a weaker spring (**i. e.** one giving a larger deflection under a given torque) was required, a softer material with a lower elastic limit was used, although it is obvious that the desired effect should have been obtained by an alteration of dimensions. The risk of permanent set and alteration of zero is increased by using a softer material.

There are three main types of hairspring: (a) the straight or torsion type used as suspensions in galvanometers and other electrical instruments, 400-day clocks, &c., and the straight type found in certain time-measuring instruments having escapements with a very high rate of oscillation; (b) the flat coiled (spiral) type used in watches; and (c) the helical type used in chronometers and in certain other scientific instruments.

Hairsprings of any type may be made from plain carbon steel, alloy steels, and other ferrous alloys (including Invar and Elinvar), the non-ferrous alloys known as phosphor-bronze, silicon-bronze and nickel-silver, silver alloys and palladium alloys; other materials have also been used. It is possible to use any metal or alloy capable of being worked into thin wire or strip with a high elastic limit and fatigue range.

### Methods of Hardening.

All the materials mentioned, when in the soft or annealed condition, have too low an elastic limit for satisfactory use as hairsprings, and must have their elastic range increased by treatment. Steel may be hardened either by heat-treatment (quenching from above the critical range, with or without a subsequent tempering) or by cold-work. Non-ferrous metals or alloys can only be hardened sufficiently by cold-work.

Steel hardened by quenching and having apparently a high "elastic limit" is not necessar-

*Presented at The Institute of Metals, March, 1927.

ily perfectly elastic up to that limit. A study of the stress-strain relations by more refined methods may show a slight curvature of the load-extension diagram, hysteresis loops on loading and unloading, and slight permanent set after application of moderate tension. It is difficult to study these effects in strip having the small cross-section of hairsprings but they may be investigated in rod of larger section treated in the same way. Elasticity may be largely restored by tempering at suitable temperatures, which may involve some softening. Quenched strip appreciably softened by tempering (*i.e.* having a lower tensile strength) may, however, have a longer range of perfect elasticity.

Departure from perfect elasticity is still more marked in steel and in non-ferrous alloys hardened by cold-work. The impairment of elasticity by cold-working operations (cold-rolling, drawing, &c.) and the restoration of elasticity by subsequent treatment have been extensively studied.* Briefly, permanent deformation of any metal or alloy, in the cold, produced by any means, tends to lower the ratio of the true elastic limit to the tensile strength, which is raised. In general, the greater the amount of deformation, the more is the elastic limit lowered and the greater is the curvature of the load-extension diagram, although the tensile strength may steadily increase. The characteristics of severely cold-drawn material are a high tensile strength, a very low true limit of proportionality, a load-extension diagram showing a gradually increasing curvature as the stress increases, and a pronounced hysteresis loop on loading and unloading. Such material is obviously unsuitable for hairsprings. Some recovery of elasticity occurs on standing at ordinary temperatures, and may be nearly complete in very mild steel and in some non-ferrous materials. Recovery of elasticity may be brought about in all cold-worked metals and alloys by heat-treatment at temperatures usually between 100° and 300° C. The treatment required depends on the composition of the material and on the nature and extent of the cold-working operations. Suitable treatments have been determined experimentally for various steels and non-ferrous materials cold-worked to different extents.

It may be pointed out that though straight hairspring strip may have been so treated as to be perfectly elastic, bending to a coiled form, or any other operation involving permanent deformation in the cold, again impairs its elasticity unless some "recovery treatment" (low-temperature heat-treatment) is applied after the spring is brought to its final form.

TABLE I.—*Hat-Treatment of Cold-Drawn Steel Strip containin* 1.2 *per cent. of Carbon.* 0.0028 *in. thick by* 0.0148 *in. wide.*

| Treatment. | | Average Breaking Load.* | |
|---|---|---|---|
| Temperature. °C. | Time. Minutes. | On Section. Lb. | Tons /in.² |
| As drawn | .... | 7.80 | 84.1 |
| 200 | 15 | 8.42 | 90.7 |
| | 30 | 8.58 | 92.4 |
| 250 | 15 | 8.44 | 90.9 |
| | 30 | 8.47 | 91 2 |
| 275 | 15 | 8.59 | 92.6 |
| | 30 | 8.87 | 95.5 |
| 300 | 15 | 8.81 | 94.9 |
| | 30 | 8.85 | 95.3 |
| 350 | 15 | 8.54 | 92 0 |
| | 30 | 8.49 | 91.5 |

*Each result is the average of at least 4 tests.

Some of the materials used for hairsprings are considered separately below.

### Carbon Steel

Carbon steel is probably the material most frequently employed. Swedish steel of high quality containing from 1 to 1-3 per cent. of carbon and very low in sulphur and phosphorus is commonly used. Quenching in oil from 750° C. has been found to be a suitable hardening treatment and gives a Brinell hardness over 650, which may be reduced to any desired extent by subsequent tempering. Tempering at a temperature between 300° and 350° C. gives a Brinell hardness number usually between 520 and 400, covering the range generally suitable for hairsprings.

The same high-carbon steel may also be hardened to the required degree by cold-work; it is drawn into wire of circular or elliptical section, and if required in the form of strip it is drawn to a size which on rolling will produce strip of the requisite width and thickness. Small variations in the wire sometimes give a rolled ribbon which is not straight, and this is then rectified by drawing through a die. Wire or strip with a general lateral curvature or not of uniform dimensions is not suitable for hairsprings.

The chief disadvantage of plain carbon steel for hairsprings is its liability to corrosion. General corrosion weakens the hairspring by reduction of its effective thickness, but more frequent and troublesome are small rust spots, which may start fracture, particularly in springs used in rapidly moving escapements. The thin continuous oxide coating usually left after tempering tends to retard corrosion, and the use of a film of good watch oil, applied by wiping or by dipping the springs into oil or into a solution of the oil in benzene, has been found effective in preventing corrosion, provided the coating is continuous.

Cold-drawn and tempered

*See, for example, R. H. Greaves. "Gun Wire," Research Department, Woolwich, R. D. Report, No. 60 (H.M. Stationery Office, 1924), and previous publications to which reference is made in that report.

steel hairspring strip containing 1.2 per cent. of carbon has been used successfully in the form of straight hairspring escapements giving more than 80 beats per second. Table I. shows the effect of low-temperature heat-treatment or tempering on maximum load in tension. The effect on elastic limit is much greater, but cannot be shown in tensile tests on such thin strip.

Since the strip was required in the straight form for the hairsprings and tensile tests, it was clamped during treatment between plane steel faces, which allowed expansion in a longitudinal direction but prevented bending.

### Ferrous Alloys.

Certain steels containing high percentages of nickel, or both nickel and chromium, offer special advantages for use as hairsprings. They resist corrosion, some to a very remarkable extent, and a number are non-magnetic.

The alloys of French origin, Invar and Elinvar, are the best known of these, and both have been used for hairsprings. Invar contains 36 per cent, of nickel, and has a temperature coefficient of linear expansion of only $0{\cdot}009 \times 10^{-4}$ per ° C. (compared with $0{\cdot}105$ to $0{\cdot}116 \times 10^{-4}$ for ordinary steel) over the range of temperatures in the neighbourhood of 20° C. Elinvar, the more recently developed alloy, contains about 12 per cent of chromium and 36 per cent. of nickel, and after suitable treatment has a practically constant elastic modulus over a range of temperatures between — 50° and + 100° C.; this property is regarded as being more important than low coefficient of expansion in hairsprings. The modulus of elasticity (E) of Elinvar is given as 11,400 to 12,000 tons/in.$^2$, compared with 13,400 tons/in.$^2$ for high-carbon steel of the type used in hairsprings.

Elinvar can hardly be regarded as a steel, and like non-ferrous alloys can only be hardened by cold-working operations. The requisite properties before cold-working are secured by air cooling or quenching from 800°C. In order to restore the elastic properties impaired by the cold-working operations, the hairsprings should be heated to temperatures between 350° and 600° C. The appropriate temperature and time of treatment depend on the degree to which the Elinvar has been cold-worked.

Elinvar is highly resistant to corrosion.

### Non-Ferrous Alloys.

The main advantage of steel, when of suitable composition and treatment, is the much longer range of perfect elasticity (i.e. the much higher elastic limit) in comparison with non-ferrous alloys. The difference is so considerable that it is rarely necessary to use steel in the hardest possible condition, while non-ferrous alloys have usually to be hardened by cold-work nearly to the maximum extent. One consequence of this is that steel or ferrous alloy hairsprings may be both harder and tougher than non-ferrous springs, and may therefore be less liable to local injury (as in assembling into instruments) or to failure to fracture if local injury occurs. Non-ferrous alloys are commonly more resistant to corrosion than most of the steels used for hairsprings.

Hairsprings made of non-ferrous metals, pure or approximately pure, would in some cases have a low electrical resistance, a decided advantage in some types of electrical instrument. Even when severely cold-worked the commoner non-ferrous metals are, however, too soft for use as hairsprings, with the possible exception of some forms of galvanometer strip suspensions.

Phosphor-bronze and nickel-silver have been much used for hairsprings, but the former appears to have largely replaced the latter, probably because of the greater uniformity in composition which can be obtained with phosphor-bronze, which when of suitable composition has the further advantage of being practically free from the liability to season-crack and fire-crack. Silver alloys have also been used to a limited extent in certain instruments.

TABLE II.—*Properties of Phosphor-Bronze Hairspring Strip.*

| Method of Manufacture | Composition. Copper. Per cent. | Tin. Per cent. | Phosphorus. Per cent. | Dimensions. Inch. Thickness. | Width. | Breaking Load. Average On Section. Lb. | Tons /in.$^2$ |
|---|---|---|---|---|---|---|---|
| Strip made in hand-operated draw-benches and rolls | 95.2 | 4.4 | 0.19 | 0.0041 | 0.0170 | 10:18 | 65.2 |
| | 94.5 | 5.3 | 0.15 | 0.0038 | 0.0160 | 10.05 | 73.8 |
| | 93.3 | 6.4 | 0.20 | 0.0042 | 0.0167 | 11.42 | 72.7 |
| | 93.2 | 6.6 | 0.14 | 0.0038 | 0.0159 | 10.15 | 75.0 |
| | 93.3 | 6.5 | 0.18 | 0.0038 | 0.0147 | 10.18 | 81.3 |
| | 93.5 | 6.3 | 0.12 | 0.0032 | 0.0150 | 8.63 | 80.3 |
| Strip made in power draw-benches and rolls | 94.2 | 5.5 | 0.20 | 0.0038 | 0.0160 | 9.89 | 72.6 |
| | 92.8 | 6.3 | 0.19 | 0.0042 | 0.0157 | 9.09 | 61.6* |
| | 93.0 | 6.6 | 0.20 | 0.0038 | 0.0147 | 10.27 | 82.0 |

*Less severely cold-worked than the other samples.

Phosphor-bronze free from zinc and containing not more than 6 per cent. of tin and 0.2 per cent. of phosphorus is commonly used. In tests made in the Research Department the phosphor-bronze was cold-drawn into wire of circular section, which was then rolled and finally drawn to the desired width and thickness; the resulting properties are shown in Table II. The rolling and drawing processes must be of a type which will not produce cracks or irregularities of any kind in the edge of the strip, since such defects tend to produce fractures in hairsprings, particularly in those of fast-moving escapements.

The higher tin contents con-

(*Continued on page 136*)

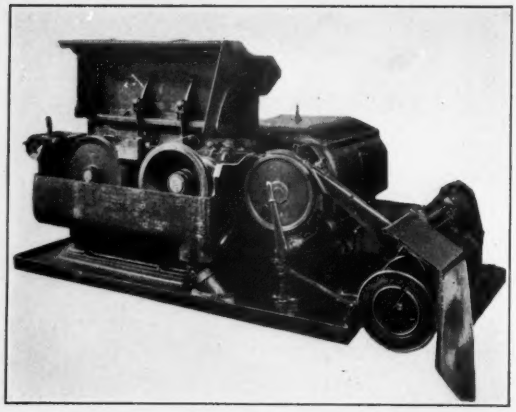


Fig. 1—The new heavy wire machine, arranged for spooling.

# New Developments in Copper Wire Manufacture

**Part II**

## A detailed discussion of modern wire drawing machines

*By John L. Alden*
*Western Electric Engineer*

THE first article of this series which appeared in the March issue gave a general description of the bare wire mill in operation at the Western Electric Company's Hawthorne Works in Chicago. The striking features of the wire drawing machines of that mill are here presented in greater detail. The heavy wire or No. 1 machine is shown in Figure 1 arranged for spooling. This is a cone tandem ten-die machine finishing No. 16 B & S and heavier from the rod at a finishing speed of 1750 ft. per minute although some heads are running at 2000 ft. per minute. Entering the grease box at the left of the illustration, the rod is drawn through the break-down die. It then passes into the drawing chamber wrapping successively around the steps of the drawing cone and the free running idler sheaves, being drawn through one die at each step. At the exit end of the chamber the wire receives its final reduction by the finishing die through which it is drawn by the capstan sheave appearing at the center of the photograph. As the wire is delivered from the capstan it is wound on a take-up reel.

### Take-up Spools

The take-up spools and reels used on this machine are of heavy pressed steel construction designed to resist deformation under severe working conditions. The bore is unusually large, thereby adapting them for annealing purposes. The large bore has the further advantage of permitting rigid and true-running arbors. The connection between the arbor and the reel is by means of a bayonet lock which enables the operator to change reels with minimum effort. So that either 240 lb. or 60 lb. spools may be used on this machine, interchangeable take-up units are provided. An accurate traverse motion for distributing the wire insures uniform winding thereby eliminating all respooling. The same machine appears in Figure 2 equipped with a block take-up which is interchangeable with the spooling mechanism just described. Two sizes of block are available and a pneumatic stripper hoist is built into each block assembly. Behind the block housing appears the corner of the bundling table which is so placed that the swinging arm of the stripper hoist drops the coils in the most advantageous position for tying.

### The Drawing Cones

Since the drawing cone is driven continuously from a constant speed motor, a powerful clutch is mounted on the shaft of the capstan drawing the wire through the finishing die. To overcome the momentum of revolving parts, a suitable brake is interconnected with the clutch so that as the latter is disengaged the brake is applied. The drawing roll for the break-down die is keyed to the idler sheave shaft which is driven at a reduced speed from the drawing cone shaft. Because of the

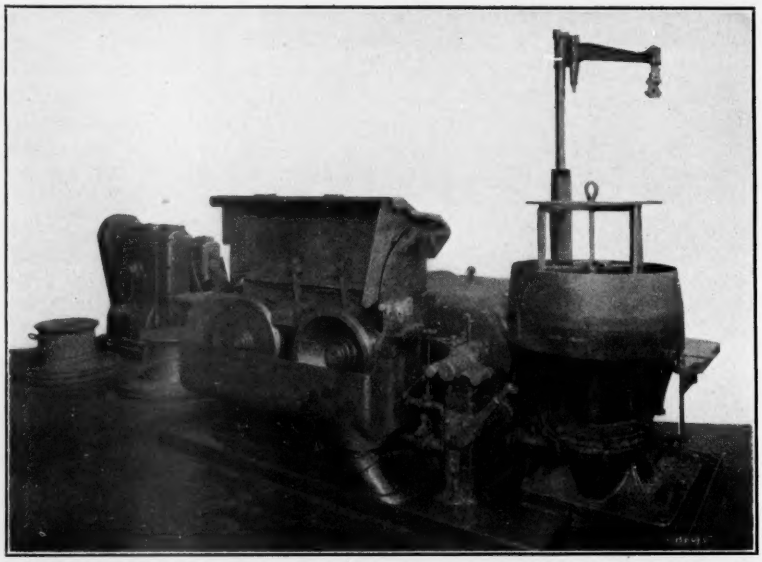


Fig. 2—The machine shown in Fig. 1 equipped with a block take-up. Note the two swifts and die-stringer at left.

speed reduction, it is possible, without excessive slip, to make the first roll, which handles the heaviest wire, of large diameter. The main drawing cone is made in two sections so that the small end on which most of the wear occurs may be replaced independently of the large end. Although the idler shaft is chain-driven, the idler pulleys themselves run free so that they may adjust their speeds to that of the wire. Both the drawing cone shaft and the idler pulley shaft run in massive bronze sleeve bearings. All of the bearings on the machine are provided with flooded lubrication.

The grease box containing the first die is adjustable laterally so as to align the die with the proper step of the drawing cone when using less than the full complement of dies. The die block for the eight intermediate dies is cored for the circulation of drawing lubricant. A suitable orifice is provided at each die projecting a generous flow of compound onto the wire at the die. Additional distributing pipes and nozzles deliver compound to the surfaces of the drawing cone and idler sheaves and a separate nozzle drives a high pressure jet into the throat of the finishing die. The latter is either a revolving or a stationary die as circumstances require. Attention is directed to the fact that the tank of the machine is merely a catch basin from which the drawing lubricant is returned to storage tanks in the basement. Thus, it is unnecessary for the operator to dip his arm into the steaming solution each time the machine is strung up.

A noteworthy feature of all of the machines of this series is the completeness with which they are enclosed and guarded. In view of the general agitation for accident prevention, it is unnecessary to refer specifically to the advantages of such guards from a safety standpoint. It is worth while, however, to point out that adequately covered wire drawing machinery assists greatly in maintining a clean mill. All splashing drawing compound is retained within the machine and except for an occasional drip the exterior of the machine is dry and free from the customary grease and soap accumulations. The entire driving mechanism is completely enclosed thereby avoiding damage to gears, chains and bearings from flying pieces of wire, dust particles and miscellaneous dirt. The guards covering the wire between the finishing die and the spool are so designed as to avoid all interference with the speed of the operator, yet they provide complete protection from flying ends in the event of broken wire or the running through of the end of the rod.

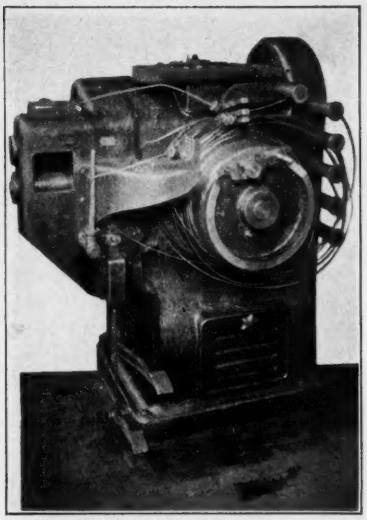


Fig. 3—The Hawthorne die stringing machine; the stationary drum in the center receives the coil after the die is properly spaced.

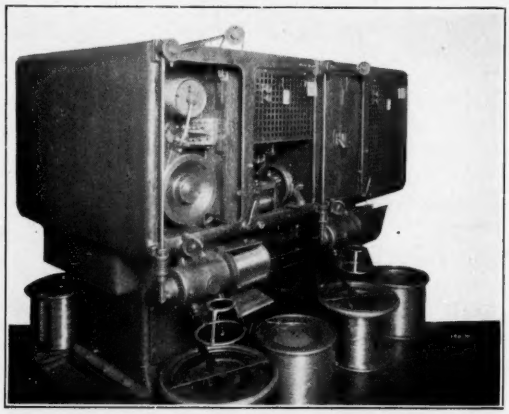


Fig. 4—A view of the intermediate size wire drawing machine. Four machines are set in a unit.

### Die-Stringers

At the extreme left of Figure 2 appear two ball bearing swifts carrying bundles of rod. The lower flanges of the revolving portions are sunk flush with the floor so that tangles and snarls are practically eliminated. An adjustable brake within the drum of the swift regulates the tension of the rod entering the machine. Behind the swifts appears the pointing and stringing machine. The latter is quite as important in its relation to output as the wire drawing machine itself for the reason that the stringing time and the condition of the coil carrying the threaded dies has appreciable bearing on the idle time of the wire drawing machine. The importance of a die stringer is often overlooked and the production of the more expensive wire drawing machine is often lessened because it is tied up to an inefficient pointer and stringer. The Hawthorne stringing machine is shown in greater detail in Figure 3. It also is motor driven, the motor being enclosed in the base of the machine. A valuable feature of this die stringer is the stationary drum concentric with the block, around which the finished coils are wrapped after each die has been properly spaced. Thus, the usual tangle of loose coils underfoot is avoided. The location of the dies on the rod is facilitated by the spacing pins located around the block.

The intermediate or No. 2 wire drawing machine is illustrated in Figure 4. This is a four-head double sides machine whose finishing sizes, ranging from No. 19 to No. 30 B & S, are drawn with a reduction of 12 full B & S numbers. The speed of the finished wire is 2500 ft. per minute. At this speed it is essential that the take-up mechanism be designed to permit adequate reduction in spool speed as the spool fills up. In the No. 2 machine the finished wire passes from the last step of the cone capstan over an idler pulley mounted on a swinging arm from which it leads to the finished wire spool. Depression of the tension arm actuates a clutch mechanism which reduces the spool surface speed to synchronize with the wire speed. Two sizes of reels are used on this machine with capacities of 60 lbs. and 10 lbs. The larger reel is also intended for use on the No. 1 machine while the small spool handles the heavier sizes on the fine wire machine.

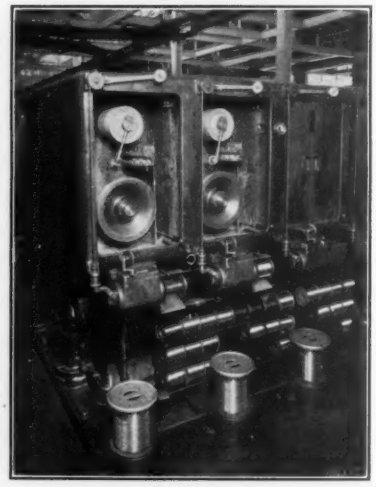


Fig. 5—A close view of the fine wire drawing machines.

Maintenance matters have been carefully considered in the development of this type. Take-up units, cone capstan assemblies and other elements are designed for complete interchangeability. The cone capstans are made so that the rear half on which most of the wear takes place may be replaced independ-

(*Continued on page 131*)

# Direct Sales vs. Institutional Advertising

## Large wire firm by advertising individual products has made whole line better known

MANY large business enterprises that would like to advertise believe they cannot, except in an institutional style, because their products are staples—sold in bulk at so much a pound or so much a foot; commodities which have a more or less standard market value but are subject to price variation even as the price of butter and eggs varies.

Every advertising man has encountered this problem some time or other. Here is the way one manufacturer is overcoming it.

The Buffalo Wire Works Company, Inc., Buffalo, N. Y., has been making wire and wire products for more than a half century. Practically everything made from wire is included in the line. In fact, this is so close to the literal truth that a slogan used extensively by the company suggests this very idea.

But to say the line includes everything made from wire does not tell the story very definitely to the consumer and to tell it more exactly in small space is next to impossible, for the Buffalo line consists of hundreds of items. Just to list the general classifications such as fencing, wire cloth and so on would make a considerable list without attempting to go into the particular uses to which each class of products is applied. Manufacturers and big buyers, of course, receive the full story in the form of a general catalog but this does not reach the individual consumer whose need for some wire product though urgent, may be infrequent—perhaps a bit of fence for the back-yard poultry run or a spark screen for the fireplace.

To increase the use of wire cloth the company began the manufacture of such articles as portable fencing, fire fenders, chimney guards, window guards, folding gates and other specialties in the making of which they had a big advantage because they had all the machinery and equipment necessary. It gave them a profitable added volume of business.

In the consumer advertising of the Buffalo Wire Works Company one specialty at a time was featured. The campaign began with a portable fence which was advertised in publications going to professional breeders of dogs and in more general publications reaching people likely to have homes in the country where they can raise dogs or chickens as a hobby. The copy does not seek to sell the whole Buffalo line but simply one specialty, for instance, the portable fence. It tells of the quality and how easily the fence can bet set up.

The local market is covered by newspaper advertising featuring such specialties as chimney guards, fire fenders, machinery guards window guards and other products made from wire cloth. The purpose is two-fold: First to sell the product advertised from week to week, and, second, to suggest that all needs involving wire cloth can be supplied. For each product practical, common-sense selling points are found to appeal to the user.

The company has found that this campaign is accomplishing a two-fold purpose; actually selling the specialty advertised and making the whole line better known.

Here is one way in which a

(*Continued on page 131*)

# Aluminum Wire

## The rapid development of aluminum wire manufacture—Replacement of other metals by aluminum in some wire products

*By Morris A. Hall, M. E.*
*Consulting Engineer, White Plains, N. Y.*

SCIENCE knows no impossibilities; not so very long ago such everyday improvements as wireless telegraphy, radio, airplanes, etc., seemed impossible to all. Aluminum—a short time ago a scientific curiosity—is now the metal of the future and will eventually take the place of 80 per cent of the iron used and of practically all iron applied to electrical industries.

A queer contradictory substance aluminum is; in the form of sulphate it prevents fire and renders combustible material non-inflammable; as a powder it produces the quickest burning and the highest temperatures. In the same form it gives us an explosive of frightful power for destruction; in the form of plates it revolutionizes electrical science by making direct current from alternating. Mix small granules of this metal with mercury, throw this into water and it will disassociate the water, liberating hydrogen in pure form.

### Possibilities Far-reaching.

There are possibilities in almost every form of human endeavor; these things are so far-reaching that one can not begin to think about all of them, says Dr. O. E. Reinhold, prominent experimenter in this metal. Yet the metal is just 100 years old; just that long ago Wohler produced the first "Baby Silver Clay" as it was then called because of its silver-white color and the fact that it was extracted from clay.

Here, we are most interested in the wire and those qualities of aluminum wire which predict its replacement of other metals. The development of the wire branch has been remarkable and the progress in use of aluminum wire, rapid. Large use is made of aluminum for wire brushes for various purposes. Where nitric acid is used extensively for cleaning, these brushes have replaced all others, the handles being made somewhat acid-proof by boiling in paraffin.

In domestic uses, very handsome effects are obtained with containers of aluminum wire, for knives and forks, for fruits and salads, for vegetable baskets to be used in stores or homes; various flower stands, egg boilers, egg beaters, table lamp and other shades, bird cages, muzzles, hair pins, crocheting needles, hooks and eyes for tailoring purposes. These latter are well liked especially for wearing apparel of the best quality and the lightest shades of color. Tinned hooks and eyes where the tinning process for coating was used, rusted in a very short time and the material stained the fabric unless brass were used. To avoid this, hard drawn aluminum wire of a special mixture is substituted in the same size wire.

Even woven aluminum wire material is now in use. As adopted for court affairs, on officer's uniforms and the like, it shows off like silver. Of course this is not the pure metal but contains 12½ per cent of silver. Wonderful effects are created by turning thin aluminum or aluminum-alloy wires into tapestry-like creations for lamp shades, vase and flower pot covers, for dress trimmings, and open portiers though expensive are stylish and widely used.

### Aluminum Most Important to Electrical Industries.

The most important and valuable development has made itself known in the electrical world. Until recently, electrical engineers treated this metal very unfairly, holding that it was without value in their work, but time has proved the contrary. The following technical data will make plain the advantages of aluminum for these purposes. In these, the best obtainable quality is considered, and the tests results from a number of unquestionable authorities. The Heddernheimer Co., Frankfort-on-Main, fixed the percentage of conductivity of aluminum wire as 59 per cent that of copper. Page in Belfort, obtained slightly higher percentages as this table shows:

Table I—Qualities of Pure Aluminum Wire*

| | Annealed Wire | | Hard-drawn Wire | |
|---|---|---|---|---|
| Resistance per meter | 0.00919 | Ohms | 0.009275 | Ohoms |
| Resistance of wire, 1 sq. m. cross section, per kilometer | 28.8594 | " | 29.149 | " |
| Resistance of copper wire, same dimensions | 17.9 | " | 17.9 | " |
| Ratio of conductivity | 62% | | 61% | |

*Wire of 2.687 density, 2 mm. diameter. According to Page, Belfort.

### Types of Aluminum

Minet's percentage results differed only in the second and third decimal. Using American aluminum, some scrap sheeting, some ingots, Reinhold cast small rods, cleaned the metal thorcughly, then drew this to wire with a cross section of 1 sq. mm. Taking copper as a unit of measurement, these results were obtained:

(*Continued on page 132*)

# Heat Treating Cold-headed Bolts

By V. E. Hillman*
*Metallurgist for Crompton & Knowles Loom Works*

CONSIDERABLE interest is attached to the metallurgical practice involved in the fabrication of cold headed bolts. The history of the art reverts back to the early Egyptians who used hand formed rivets in the construction of their various types of implements. The first commercial development of the process took place in England in 1760, when two brothers, John and William Wyatt, constructed a machine for heading wood screws. Thirty-four years later, a "cold header" was developed and patented in America. The cold heading industry has made rapid strides during the past decade and to-

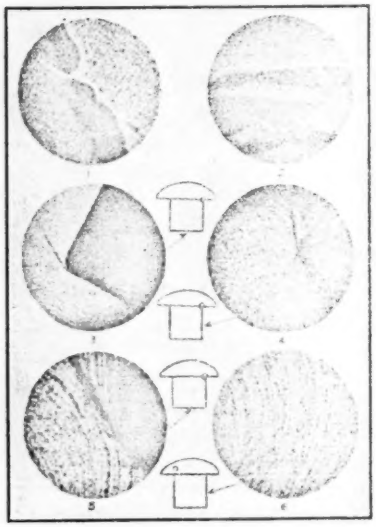


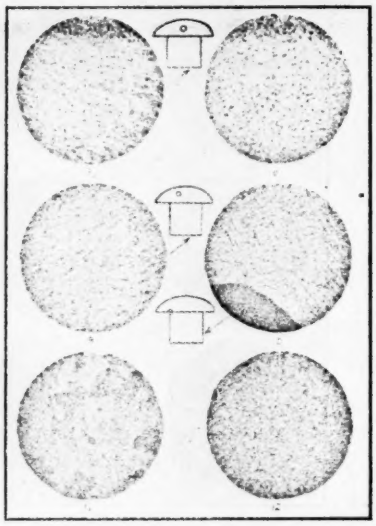
Fig. 1-6—Photomicrographs of cold-headed bolts during fabrication. Small circles in sketches show location of photomicrographs. Figs. 1, 2, 5 and 6 are X72. Fig. 3 and 4 are X33.

day enormous quantities of bolts ¼-inch and smaller are being made by this process. These remarks apply particularly to stove and tap bolts, machine screws, cultivator bolts, wood screws, and sink bolts. Metallurgists contributed their share of thoughtful attention to the advancement of the art by developing a steel that would sustain the duty imposed upon it.

*Reprinted from Iron Trade Review.

### Effect of Cold-work

The term "cold work," implies that energy is expended on the metal when its temperature is below the critical range. The microstructure of the metal prior to the application of cold work consists of an aggregate of crystalline grains or cells, each grain being a structural unit. It may suffer rupture or deformation; it may be enlarged, elongated, stressed, or restored to its normal size and shape. When the metal is subjected to mechanical pressure, the crystals are crushed and intimately mixed. Cold work has an embrittling effect upon the metal and the grains which were originally equiaxed are elongated, assuming a ropy appearance resembling fiber. In brief the grains lose their original identity. This change in microstructure alters the physical properties of the steel. The elastic limit tensile strength, specific gravity, and hardness are increased, whereas the percentage elongation and reduction of area are diminished. There is a limit to the amount of cold work which a piece of steel will sustain. Therefore the cold working of the metal must be interrupted from time to time to relieve the internal stresses which have been developed. In other words, if the strained steel be heated to above its critical range, for 15 minutes at 1650 degrees Fahr. and quenched, the elongated grain fibers will be effaced and renewed toughness will be conferred on the metal. The restoration of the ferrite and pearlite grains will permit the application of additional cold work; thus cold headed bolt manufac-



Figs. 7-12—Showing desirable structure resulting from proper heat treatment. Figs. 7-11 are X72. Fig. 21 is X36.

turers usually resort to this thermal treatment.

A lower annealing temperature, 1150 degrees Fahr. for one hour, will also suffice to partially remove the embrittling effect of cold work. It should be borne in mind, however, that only the strained ferrite grains are influenced by the lower annealing temperature. The pearlite particles remain in their distorted state. Annealing below the critical range has a dual advantage, namely the operation is less expensive and the scale nuisance is abated. A comparison of the two heat treatments indicates that the higher annealing temperature produces maximum softness, although the difference in the Brinell values is not appreciable. Certain low annealing temperatures will cause crystallization if the grains have not been sufficiently strained.

### Critical Strain

When the metal has suffered only a slight amount of distortion, an annealing temperature between 1280 and 1380 degrees Fahr. should be avoided, lest a coarse structure may result. In rivets, for instance, where merely a small volume of stock has been upset, it is mandatory to anneal below 1280 or above 1380 degrees Fahr. The above law does not apply to grains that

have been subjected to an inordinate amount of cold work, because the distortion is sufficient to render the danger range, 1280-1380 degrees Fahr. inoperative. Light cold works, however, with an anneal between 1280 and 1380 degrees Fahr., will produce a fiery, coarse, crystalline structure. Consequently, crystallization is produced by annealing a critically strained bolt within a certain temperature range. The foregoing remarks apply particularly to steel of the following analysis: Carbon 0.10 to 0.20 manganese 0.30 to 0.40, sulphur 0.05, and phosphorus 0.025 percent.

Soft basic steel is well adapted for the cold heading process. The carbon content in the metal, however, should be regulated carefully. It is a well recognized fact that if an attempt be made to upset a piece of high carbon stock, the steel will simply bend over; whereas, material of the proper analysis, 0.10 to 0.20 percent carbon, will flow readily into a compact mass. It is necessary to regulate the phosphorus content in steel which is to be subjected to the cold heating operation. The use of basic stock, however, implies that the percentage of phosphorus of necessity will be negligible. There is a limit to the volume of metal that can be fabricated into the head of a bolt. The maximum length of stock which can be formed into the head is equivalent to seven times the diameter of the rod which is being upset. That is to say, if the diameter of the rod be ¼-inch then it is possible to crush 1¾ linear inches into the head. These tolerances should be followed if "cold shuts" are to be the exception and not the rule. As shown by Fig. 13, maximum upset limits may be expressed as follows:

Volume ABCD = Volume EFG

AB = 7 BC

The reliability of a cold headed bolt is dependent upon the number of blows it received during the fabrication process. The limit of stock which can be compressed into the head by a single blow is two and one-half times the diameter of the rod. Cold headed bolts of commerce are generally subjected to two or three blows. However, there are instances, where four, five, and six blows are required to effect a reliable upset.

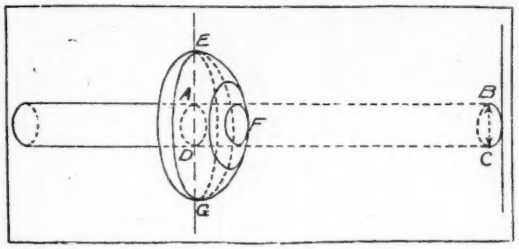



Fig. 13 — Sketch showing the maximum amount of stock which may be upset into the head of a bolt without danger from "cold shuts".

**Injuries Due to Cold-heading**

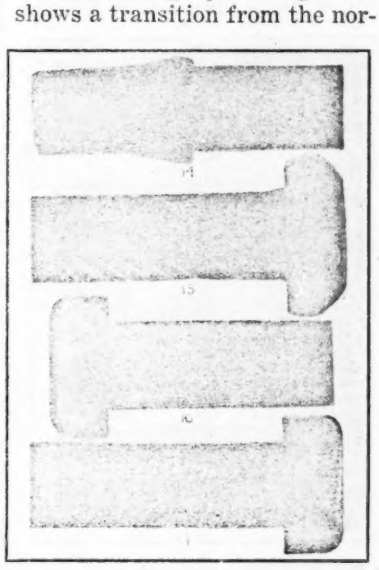
When bolts are cold headed, certain injuries are likely to manifest themselves during the process of fabrication. A "cold shut" is shown in photomicrograph Fig. 1. This defect was occasioned by attempting to upset too much stock. The flow of the metal at one point is clearly shown. Note the isthmus. Another instance of a "cold shut" is shown in the photomicrograph of Fig. 2. Observe the strained condition of the metal in the center of the picture at the extreme left and right. The imperfect flow of the metal is pronounced.

Photomicrograph Fig. 3 illustrates the manner in which a crack may develop at the junction of the head and the shank. The sharp angle acts as a seat of rupture. Photomicrograph Fig. 4 shows the highly strained appearance of the grains in the vicinity of the rupture. Note the elongated ferrite band which resembles a French curve. Photomicrograph Fig. 5 depicts the banded structure of the strained ferrite grains. Observe that the lines of deformation assume a different direction on either side of the cavity. Moreover, the severely strained areas gradually increase in intensity as the crevice is approached.

Photomicrograph Fig. 6 portrays the elongation of the ferrite and pearlite grains. This print shows the flattened crystals incident to the forming of the head. Fig. 7 is another representation of the effects of cold work. The compressive force of the heading operation is responsible for this pattern. Photomicrograph Fig. 8 shows how the grains can be restored to their original size and shape. It was necessary, however, to heat the specimen above the critical range to remove the last vestige of cold work. Photomicrograph Fig. 9 illustrates a slightly strained specimen which would become crystallized if annealed between 1280 and 1380 degrees Fahr. The grains have suffered a very small amount of distortion. The fiber-like appearance of the metal is just beginning to manifest itself.

Photomicrograph Fig. 10 shows a transition from the normal grain size to the highly strained fibers. Strained and unstrained areas may be found

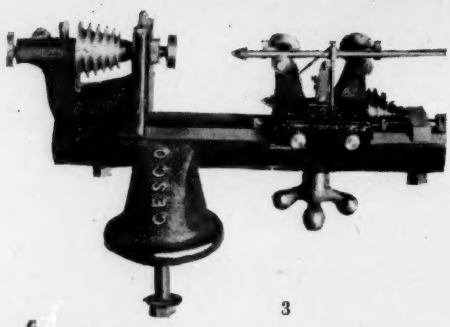
(*Continued on page 132*)



Figs. 14-17—Microscopic etchings of bolts after upsetting operations, indicating flow of metal and accompanying distortion. (Slightly over twice actual size).

# Manufacture and Care of Diamond Dies

*By Rudolf Wildermann, E. E.*



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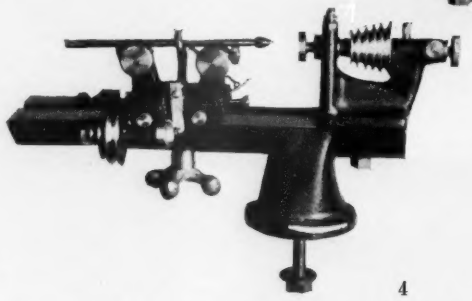

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Figs. 3 and 4—A horizontal finishing lathe for lapping and tapering the die hole. The lapping needle oscillates back and forth.

HARD materials of every description have been tried for the use of dies for drawing fine wires. But to-day such drawing is done almost exclusively through diamond dies, particularly for finer gages, wires up to .060" in diameter. Lately stones made of a ferro-tungsten alloy have been adopted for the hot drawing of refractory and hard metals, but the use of such dies is limited to that particular field.

South-African and Brasilian diamonds give the best results. Thin or flat pieces are not used because they break too easily. Care is taken to put the hole across the grain of the diamond. The average size of stones for fine holes is from ¼ to ¾ carats, but for larger wires diamonds up to 4 carats are used.

The shapes given to the holes in the diamond are shown in A, B and C in Figure 1. The shape in C is most commonly used to-day. The diamond at the narrowest point of the hole is the "size" of the die. It is kept within .0001" limit of the specified size. The wear of a die depends upon the hardness of the material to be drawn and is a direct function of the number of feet of wire drawn through it. The drawing speed does not influence the wear in any noticeable way.

Suitable diamonds are flattened, centered on opposite sides, drilled, coned and mounted or they are mounted before the drilling. If we proceed according to the first method, care must be taken that the stone is correctly mounted in the steel frame. If the direction of the hole is not perpendicular to the mounting, the wires will be drawn to an oval shape. For hot mounting the stone is ordinarily held between centers in a device not unlike a small drill press.

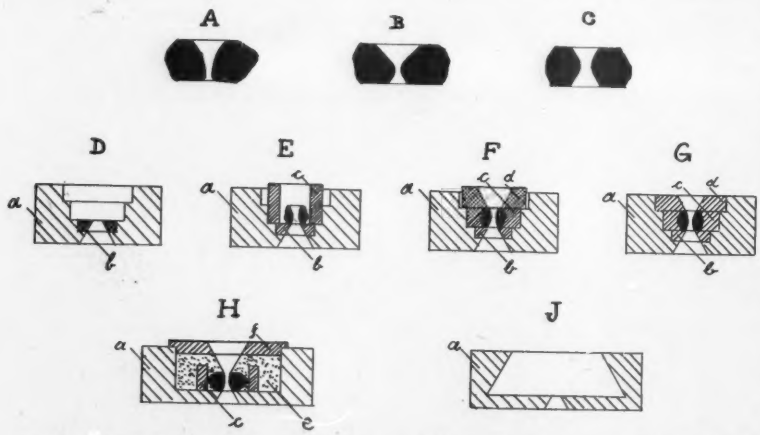



Fig. 1—Various methods of mounting the diamond. D, E, F, and G show cold mounting in successive steps. H, shows the hot mounting.

Various methods of mounting are illustrated in Figure 1. D, E, F and G show the successive steps of cold mounting. First a brass or copper ring (b) is placed into the circular steel shell (a). Figure E shows the next step: A brass or copper sleeve (c) is set into the shell around the diamond and by steadily increased pressure that sleeve is moulded around the diamond. Then another ring (d) is set upon (c) (Figure 1, F) and pressed into the shell and thus the final assembly shown in G is obtained.

Figure 1, H shows a method of hot mounting. The diamond is placed into the shell with a light brass sleeve (c) around it. After centering the diamond with the above described device, brass or silver solder (e) is filled in and set under pressure and covered up by a plate (f). A most commonly used shell for hot mounting is shown in Figure 1, J.

The drilling of a diamond die may take several day's time, sometimes it runs into weeks. If an experienced operator gives this work all the necessary attention, there still remains two factors to be considered as governing the time required for the drilling operation; the first one is the hardness of the diamond; the second one is the tool used for this operation. Like all

work done on the diamond the drilling is an abrasive operation, and since—on account of the small diameter of the drilling needle—the peripheral speed at the point of operation is low compared to speed of rotation, the needle is operated at the highest speed which it is mechanically possible to obtain. To reduce the power-losses and the maintenance cost to a minimum all unnecessary drives, idler shafts and pulleys, countershafs and bearings are avoided in the up-to-date diamond die drilling machinery. Figure 2 shows a modern machine of this type.

The motor is mounted right on the machine and directly coupled to a countershaft on the back of the frame. On this shaft are pulleys, each of which drives one of the drilling spindles on the heads of the machine. A light strong cord serves as belt drive between the large driving pulleys and the spindles. The cord travels from the top of the driving pulleys around the small pulleys on the spindles and from there revolves over aluminum idler pulleys to the bottom of the driving pulleys. Right in back of the heads, also driven from the countershaft, is a camshaft, by means of which the drilling spindles, revolving at a very high rate of speed, are lifted up and dropped again upon the die about 90 times per minute. At their lower ends the spindles carry either a pin vise into which the drilling needle is clamped or a tapered chuck into which the needle is fastened by means of sealing wax. The weight of the spindle is chosen according to the size of the needle and the hole to be drilled. It is made as heavy as possible without bending the needle or breaking its point.

Below the spindle, in alignment with it, is a round table. The die is either mounted on it with sealing wax or set into a cup on top of it. The table can be raised or lowered by means of an adjustment screw at the bottom, and by means of a set screw on the side it is locked in position.

On these latest machines the heads form one unit, with the spindle on top and the table below, but they are not mechanically interlocked with the camshaft. Any head may therefore be taken off the machine without stopping the whole machine and without interrupting the operation on the other heads. A small grinder, mounted with the machine, serves to sharpen the needles.

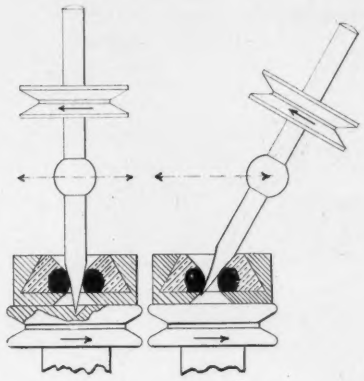


Fig. 5—A type of vertical polishing and lapping machine. It requires less attention than that shown in Fig. 3, and is of higher efficiency.

After the die is drilled its entrance and exit are lapped and tapered to the desired angles. Figures 3 and 4 show a horizontal finishing lathe for this purpose. The needle oscillates back and forth and the die rotates at a high speed. The head-stock of the little lathe consist of a spindle, running between centers with a step pulley; the front end of the spindle extends through the center support in which it rests, and carries a cup formed chuck in which the die is mounted. The die is faced by a caterpillar-slide rest, consisting of a rod with a pin vise for the needle at one end, two grooved rollers in which rests the rod and a cam movement, as shown in the back view of Figure 4. The rollers can be adjusted up and down, thus permitting a setting of the needle at an angle with the centerline of the head-stock; for lapping purposes the needle is set in line with the head-stock; for coning the die hole entrance, the needle is set at an angle, point of the needle resting in the die hole. The tension, by which the needle drives into the hole when the cam allows it movement in that direction, is supplied by an elastic band. Whereas in the drilling operation the needle has to be frequently sharpened, but the diamond powder feeds continuously into the hole by reason of its weight, in this operation the needle sharpens itself most of the time, but the powder has to be fed to it oftener on account of the operation in horizontal position. Vertical machines for this work are also on the market, which require less attention in the feeding of powder.

Such machine is shown in Figure 5. It serves to lap and cone new dies as well as to polish used dies, to make them

(*Continued on page 140*)

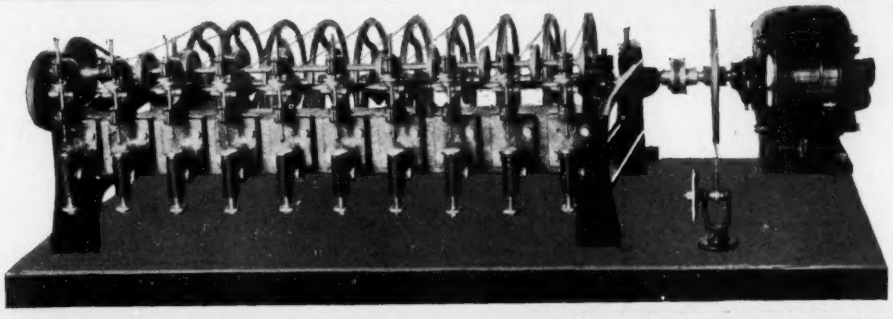


Fig. 2—A multiple head diamond die drilling machine of an up-to-date design.

Sleeper & Hartley
TRADE MARK

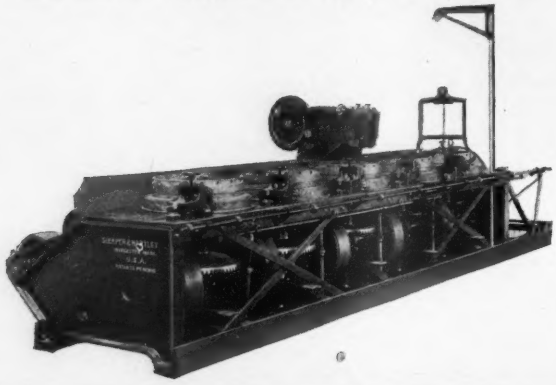
# PRACTICAL CONTINUOUS WIRE

These Machines Go Into Production at once—Re

## Rod Frame

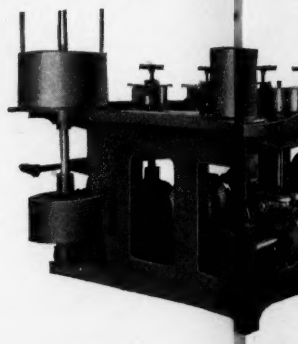
(No. 5—14 or 15 wire)
Patented June 3, 1924—May 12, 1925—others pending

All Ball or Roller Bearings
No Differential Gearing.
Automatic Compensation for Speeds of Heads.



## Double 5-Drafty, D

No. 14 to No. 23. h or lo
3 to 4 Blocks verage
No. 14 to 19—4 h 1400 l
No. 14 to 20—5 h 1100 l



## Spring Coiling Machinery

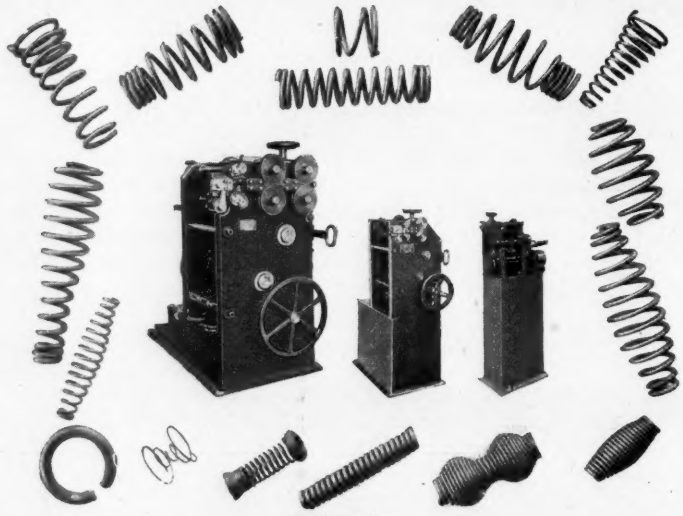
of every description.

For example, we offer:

## Universal Spring Coiling Machines

in ELEVEN Sizes

handling oil-tempered wire from .004" to ⅝" diam. These machines produce spring forms as illustrated herewith at very high productive speeds.



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# IRE DRAWING MACHINERY

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## fry, Intermediate

. or low carbon wire.
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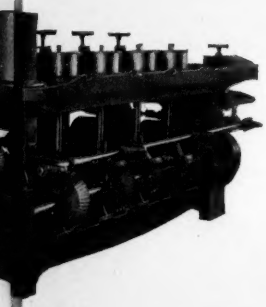
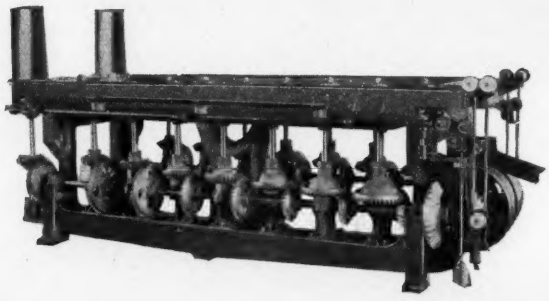
1400 lbs. per block.
1100 lbs. per block.



## Double 8-Draft Fine Wire: Wet

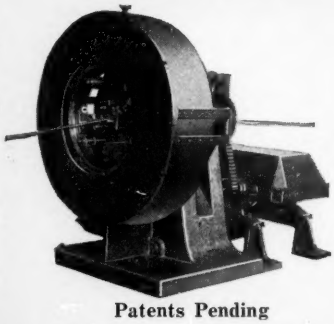
No. 22 to 36. High or low carbon wire.

6 Blocks to Average Operator, 22-33, 8-hole, 660 lbs. per day of ten hours.



# ARMORING MACHINES FOR

## "BX," PARK CABLE MOTOR WIRES, HOSE Etc., Etc.



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JAPAN—Andrews & George Co., Tokyo. SWEDEN AND FINLAND—Akt., Rylander & Asplunds, Stockholm.

MASS., U. S. A.

# EDITORIAL . IMPRESSIONS

## *Simplified Practice*

UNDER the auspices of the National Committee on Metals Utilization important steps are being taken in the direction of standardized practice. Of special interest to the wire industry are the recommendations of the committee concerning metal spools and reels.

The Technical News Bulletin of the Department of Commerce reports that "on December 2, 1926, manufacturers of metal spools and reels, representing approximately 90 per cent of the annual production of these commodities, convened at the Department of Commerce for the purpose of considering the possibilities of applying the principles of simplified practice to their products.

A committee was appointed to conduct a survey of the present conditions in the industry as a first step in the direction of framing a tentative simplified practice recommendation." (The report of the chairman of this committee will be published in the next issue of Wire & Wire Products.)

It is interesting to note the nationwide attention various trade associations are giving to the question of standardization and simplification. The importance of this question could hardly be overstressed for it bears not merely on increased efficiency in operation but on employment stabilization and on the increase of employee earning power as well.

The wire industry might very profitably carry standardization into departments other than reels and spools, though in that alone—could standardized practice be effectively established—the industry would be making tremendous gains.

In this age of research and scientific management it is hardly necessary to advance arguments in favor of standardization. We feel certain that once the work of the Division of Simplified Practice is brought to the attention of the wire industry their recommendation concerning spools and reels will meet with general approval.

## *Trade in China*

The unbalanced political situation in China and its effects on Chinese imports is of much interest to American export trade. The figures for recent hardware imports are a good index to the trade tendencies in China.

Imports of needles into China, including both those for hand and machine sewing, during 1925 were valued at $1,105,135 as compared with $1,114,150 in 1924 and $969,128 in 1923. While this is not a very large business it is significant to note that receipts from Germany and Japan together represented over 75% of the total in this group in 1925. Germany contributed in value $445,493, an increase over 1924 of $26,395, while Japan's share declined from $405,686 in 1924 to $396,223 in 1925.

The hardware trade in general, of which a large part comprises wire products, showed a decrease in 1925 from 1924 but an increase of 21% over the values for 1923. The Chinese boycott of foreign goods is chiefly responsible for this and affected imports from all countries with the exception of Germany; hardware from that country having regained much of their pre-war supremacy! When compared with 1924, the 1925 trade of Germany, Japan, Great Britain, and the United States, showed that the trade of Germany realized an increase of 14.1 per cent while all the others indicated decreases.

WIRE
& WIRE PRODUCTS

## *Aluminum Centennial*

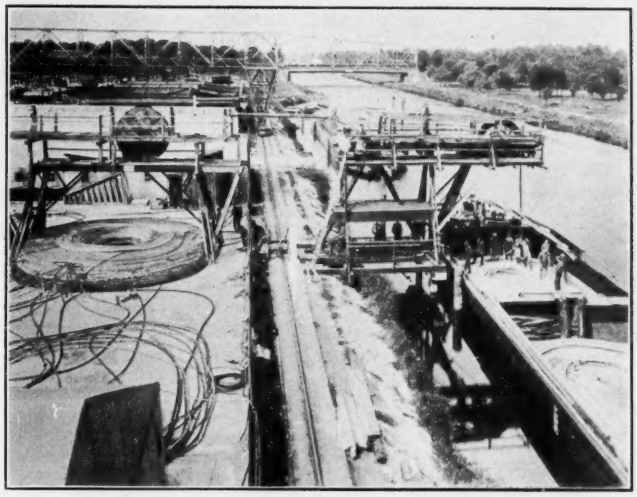
ELSEWHERE in this issue we publish an article on the development and the future possibilities of aluminum wire manufacture. In 1915 the United States used almost a hundred million pounds of aluminum and more than 9 per cent of this was in wire form. The rise of this industry from a negligible laboratory product sixty years ago forms an impressive chapter in the history of modern industrial development.

The present year marks the 100th anniversary of the first production of metallic aluminum. In 1827 Friedrich Wöhler then professor of chemistry in the University of Gottingen succeeded in isolating aluminum, the metal of clay. The aluminum Wöhler first obtained was a gray powder, but in 1845 he produced the metal in fused metallic globules. Here he let the research rest until in 1854 Deville began his attempts to produce aluminum industrially.

Still, aluminum made little progress outside the laboratory and at the Paris World Exposition in 1855 the 12 small bars exhibited there were regarded as mere scientific curiosities. But slow as was its first stage of development its subsequent rise was incredibly rapid and today its manufacture constitutes one of the largest branches of the metal trades.

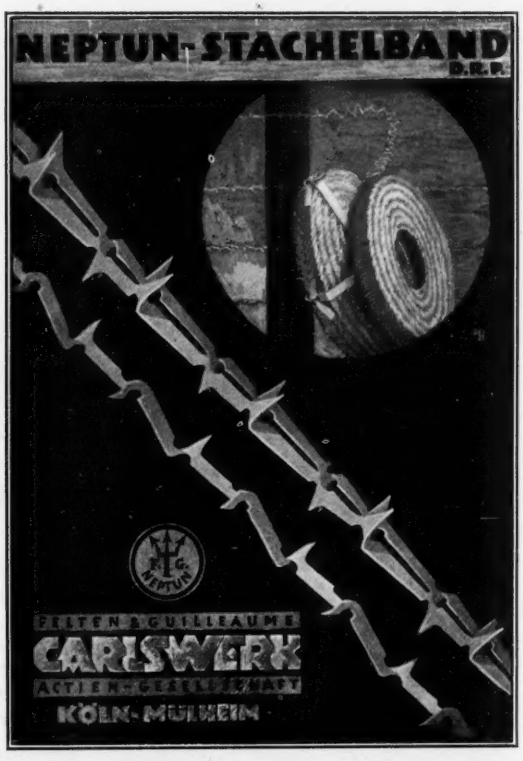
Wöhler who made this possible was one of the greatest and most industrious metallurgists of all time and on this 100th anniversary of one of his most important discoveries the world might well pause a moment in its business of living to recall his brilliant work.

# WIRE IN THE NEWS



The new cable from Germany to Denmark being laid on a canal barge to be brought out to the cable ship. The work is being done by Tiemens and Halske.

At left: A use of wire in washing sand containing gold particles is described by Agricola, the fifteenth century scholar and engineer. The illustration is from one of his books.




At right: Photo of an effective advertisement of the new barb-wire substitute manufactured by Felton & Guillaume. The new product is a punched metal strip which when distended serves as barb-wire.

If you have photographs of interest to the Wire industry, send them to Wire & Wire Products

# BOOK REVIEWS

**Pocket Technical Dictionary.**

TECHNISCHES WORTERBUCH, L. Deutsch-English, 149, p, II, English-Deutsch, 163. By Erich Krebs. Walter de Gruyter & Co., Berlin, 1926.

These two small volumes contain a judiciously compiled vocabulary of machine design and shipbuilding. No attempt has been made to present an exhaustive dictionary of technical terms. The author seems to have intended his work to be rather a ready-to-hand aid in a restricted field. In this he has very well succeeded and we can recommend these little volumes to all machine designers or others who have occasion to use the German vocabulary of mechanical Engineering. The books are of a handy pocket size.

**A Synthesis of German Engineering.**

HUTTE, II Band, 25th Edition, 1167 pages, Wilhelm Ernst & Sohn, Berlin, 1926.

This remarkable compilation of German engineering practice has in the present revised edition been brought up to date. It contains the essential principles of engineering ranging from mathematics and physics through a large variety of industrial fields. The second volume which is the subject of the present review treats with remarkable thoroughness of the mechanics of machine parts, and the prime movers; a large section is devoted to types of machinery including forming, forging, woodworking, compressed air, and welding machines. Hoisting machines and ropeways are also among the wide variety of subjects in the work.

Illumination engineering is treated briefly but very competently while about two hundred pages are devoted to electrotechnics.

A section of special interest to our readers is that treating wire rope and ropeways. Many types of these machines are discussed and abundantly illustrated. The manufacture and testing of wire rope is dealt with briefly.

Throughout, the work is characterized by a close attention to the requirements of the practical engineer and yet the editors have succeeded in combining with the practical element certain essential theoretical discussions.

The complete HUTTE comprises four volumes.

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**The Human Problem in Management.**

PERSONA ADMINISTRATION. By O. Tead, and H. C. Metcalf, Ph. D. xiv, 527 p. McGraw-Hill Book Co., New York, 1926.

This book, the first edition of which has been well received, combines with a competent scientific treatment of personnel management, a deeply human interest that enables the authors to treat their subject with singular understanding. "To day it needs no apology to maintain the thesis that in industry as in the rest of life individuals are not means to the ends of other individuals. Each individual is an end in himself. His personality is unique, significant, and precious." With this point of view the authors approach the subject of employment, education and wages basing their principles on larger economic considerations as well as on a wide practical experience. A very significant and important contribution to labor relations is offered in the chapters on Research and Joint Relations.

**Translations of Articles**

**on Galvanizing and Wire Drawing, which have appeared in European Journals, will be published in early issues of**

**Wire & Wire Products**

# NEWS of the INDUSTRY

CLARENCE S. ARMS has resigned as president and general manager of the Wheeldon Wire Co., West Brookfield, Mass., to become manager of the wire drawing machinery department, Sleeper & Hartley, Inc., Worcester, Mass.

THE Superior Wire Co., Kalamazoo, Mich., manufacturer of paper mill equipment, has taken over the local plant and business of the Mackay Wire Works, manufacturer of similar equipment. The new owner will continue the operation of the MacKay plant and will make improvements. Production will be devoted to the manufacture of wires for paper-making machines, wires for screen plates, coating mill screens, etc. William A. Biddlecome will be in charge of operations.

THE Western Electric Co., Hawthorne, Ill., will begin work soon on a multi-story addition at its local plant for the production of lead cables, reported to cost more than $150,000 with equipment.

THE American Chain Co., Bridgeport, Conn., is reported to be considering the purchase of property at Los Angeles for the construction of a new branch plant. W. B. Lashar, president, is now on the Pacific Coast with view to selection of a site. The company has arranged for a preferred stock issue of $11,000,000.

THE Judson L. Thompson Mfg. Co., Roberts Station, Waltham, Mass., manufacturer of rivets, bolts, etc., has awarded a general contract to the L. H. Shattuck Co., Manchester, N. H., for a three-story and basement addition, 50x125 ft., to cost in excess of $70,000 with equipment. Arthur F. Gray, 33 State Street, Boston, is architect.

THE Worcester Wire Works, 230 Ludlow Street, Worcester, Mass., will start work at once on a one-story, 28x147 ft., addition. Plans are private.

THE National Committee on Metals Utilization has issued rules for simplified practice in spool and reel manufacture.

## Direct Sales vs. Institutional Advertising

(*Continued from page 120*)

manufacturer of a staple may advertise without resorting to a type of advertising which does not aim at direct sales. In other words, advertise in such a way that he gets his money back with profit from the goods the advertising actually sells instead of simply depending upon increased prestige for his return.

Reprinted from The Printers' Ink.

## New Developments in Copper Wire Manufacture

(*Continued from page 120*)

ently of the front portion. To avoid overhang the entire drawing cone runs on a rigid stationary sleeve supporting it for the full length. The idler sheaves are of uniform diameter and are bushed to run on a stationary stud. Each machine is provided with its own oil pump and storage reservoir to which lubricant is returned after passing through the bearings. The oiling system is in accordance with the best machine tool and automotive practice. Unobstructed access to the drawing chamber is made possible by a special type of quick opening door which when opened lies closely against the side walls of the cabinet. When closed they are practically splash proof so that a flood of drawing compound to dies and drawing rolls may be obtained without objectionable spray. As in the case of the No. 1 machine, the draw-

(*Continued on page 139*)


*Use Oakite materials for cleaning—and save acid*

MANUFACTURERS of wire and wire products can save considerable time and money by cleaning wire before pickling. This cleaning operation removes oil, grease and dirt, enabling the acid to do its work better and quicker. Reduction in the use of acid makes savings in costs and frequently an improved wire.

Oakite materials can also be used for neutralizing an acid condition on work after pickling. It does it thoroughly and at low cost.

One of our Oakite Service Men is near you. Discuss with him the possibilities Oakite hold for you in saving acid, time and money in your plant. Ask to have him call. No obligation.

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**VIANNEY WIRE DIE WORKS**
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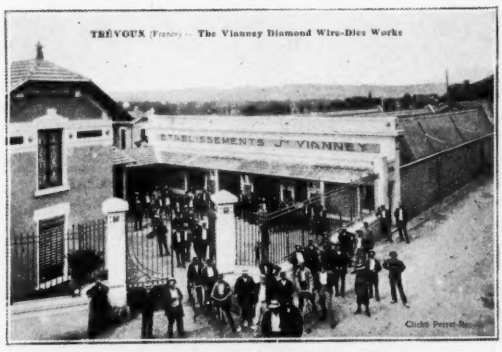


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OLDEST AND LARGEST DIAMOND DIE MAKERS

## Heat-Treating Cold Headed Bolts

(*Continud from page 123*)

in the same bolt. Photomicrograph Fig. 11 shows an enlarged grain structure produced by annealing a critically strained specimen at 1300 to 1350 degrees Fahr. Observe the abnormal grain growth. Photomicrograph Fig. 12 illustrates another region of the specimen in Fig. 11. Even though the bolt was annealed in the danger zone, a fine grain growth resulted. The reason therefor is that the metal in the subject area was sufficiently strained to prevent crystallization.

In Fig. 18 is illustrated several exhibits of cold headed bolts which failed in service. The defect may have been occasioned by one or more of the following causes: Omission of heat treatment, excessive quantity of material in the head, carbon segregation, scale, slag inclusions, ghost lines, or abnormal hardness in the rod prior to cold heading. Fig. 14 shows a microscopic etching of a bolt after the first upset. The strained grain fibers are clearly discernible. The flow of the metal may be observed by following the contour of the strain lines. The maximum deformation has taken place at the outer edge of the specimen; whereas, the intensity of distortion has decreased toward the center. The arc at the junction of the head and the shank shows the line of demarcation between the strained and unstrained areas.

Fig. 15 shows a microscopic etching after the second upset. The position of greatest strain is shown in the center of the head. That is to say, the light areas indicate the unstrained metal. The lance-like streaks, however, are strains occasioned by the polishing operation. Fig. 16 also shows the strained condition of the metal in the head. The area bounded by the arcs has suffered maximum distortion. The strained fibers resemble a whirlpool in appearance. The same remarks apply to the specimen illustrated in Fig. 17.

Figs. 19 and 20 are photographic views showing the evolution of a cold headed bolt from the rod to the finished product. Fig. 19 shows a round head, square shank bolt, cold upset, made from basic cold drawn wire. Fig. 19 **a** is a piece of material used in making the bolt; **b** the first upset; **c** the second upset; **d** annealing; **e** reheading or pressing cold; **f** heat treating; **g** trimming; **h** pointing; **i** threading. This is a cut thread.

Fig. 20 shows a hexagon head

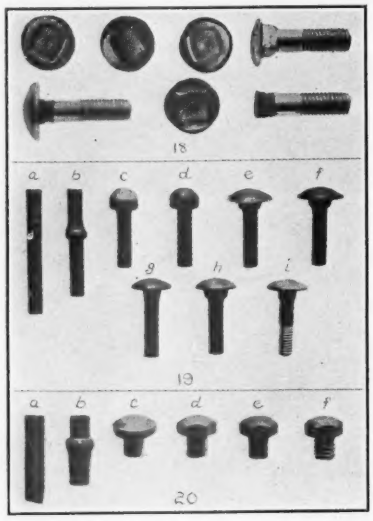



Fig. 18—Examples of bolts which failed in service. Fig. 19—Evolution of a round head, square shank bolt from cold drawn wire. Fig. 20—Evolution of hexagonal head tap bolt from cold drawn wire.

tap bolt, cold upset, made from basic cold drawn wire. Fig. 20 **a** is a piece of material used in making the bolt; **b** the first upset; **c** the second upset; **d** trimming; **e** annealing and heat treating; and **f** threading.

In conclusion, it may be said:

1. Various degrees of distortion may be found in the same bolt. Certain regions undergo slight deformation, whereas, other sections undergo extreme distortion.

2. Annealing at 1150 degrees Fahr. will remove the weakening effects of cold work.

3. Irrespective of the degree work, crystallization will not take place below 1280 or above 1380 degrees Fahr.

4. If the temperature of the furnace reaches the hazardous zone, 1280 to 1380 degrees Fahr. however, crystallization will take place only in those areas which have been slightly strained.

5. Annealing above the critical range, 1650 degrees Fahr. is preferable.

6. In this range of temperature, 1625 to 1675 degrees Fahr. and regardless of the degree of strain, crystallization will not result.

The successful manufacture of cold headed bolts demand the application of fundamental metallurgical principles. The quality and service of the finished product is therefore dependent upon an adherence to the laws of metallurgy.

## Aluminum Wire

(*Continued from page 121*)

**Table II**

| | Annealed Wire | Hard Wire |
|---|---|---|
| Swiss aluminum | 59.121% | 58.001% |
| German aluminum | 59.462 | 58.713 |
| Scrap from U. S. | 60.488 | 59.111 |
| Ingot from Alum. Co. of Amer. | 62.005 | 61.017 |

In designing and erecting aluminum power lines in Germany, it is customary to replace copper by aluminum with a wire having a cross section 1.7 times that of the copper, or 1.3 times the diameter. The specific gravity of copper being taken at 8.9 and of aluminum 2.7, the weight for equal stretches of wire with the same conductivity is expressed by the proportion of 100 for copper to 50 for aluminum.

### Aluminum Wires Shed Ice and Snow.

Another notable advantage of aluminum overhead wires is that ice or snow is rarely found on them, even in very bad weather, because of the greasy nature of this metal. This is important because a good many long-distance lines have been ruined by ice or snow. This property was discovered after a heavy storm which destroyed many copper lines through overloading by snow while hardly any injury to the aluminum lines was noticed.

Up to ⅛ in. sizes solid wire is recommended; above this, strand cables are recommended for these reasons:

A greater number of linear feet can be furnished in one piece.

There is less trouble in joining (soldering, clamping, welding).

Thinner wires can be produced with a tensile strength which exceeds that of the thicker wire.

Stranded cables have less tendency to bend through between posts.

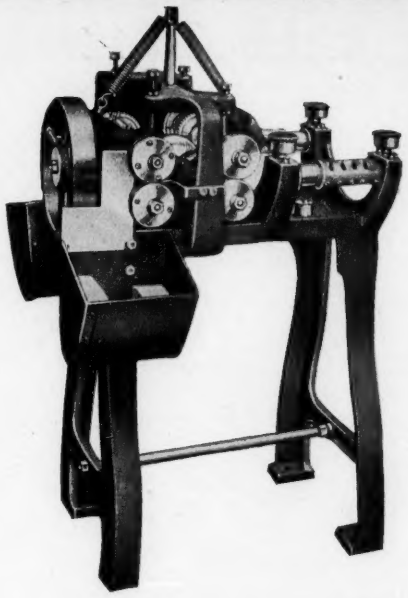
Installation is much easier and quicker, thus cheaper.

Danger of tearing or snapping off is minimized by the many separate strands.

Up to loads of 5 kilowatts, a cross section of 5 to 25 mm. is suggested. If welding is used at joints, they must be doubly lapped and painted immediately to prevent untimely corrosion. Joining by rivetting or by screwing devices of the same metal, or by soldering was preferred but recent progress in welding aluminum has eliminated much of the former oxidizing difficulty.

The sketch Fig. 1 shows a section through a satisfactory insulation tackle, a fiber tube with a galvanized iron protecting cap carrying the bolt through the brass hanger of flat disc shape with a projecting ear, the flattened aluminum conductor being suspended below this.

In the use of porcelain insulators, the best plan seems to be to loop the aluminum wire around the porcelain, then twist the end around the main wire, soldering along these twists with Noflux solder as at A, Fig. 2. Where a splice has to be made, or the work executed very quickly, or where the diameters are quite small, the torsion tube is used. This is a flat aluminum tube, the smallest size being 9¾ in. long, with just enough space inside for the two wires to be joined together. The tube has the wires inserted, then tube and wires are wound up or twisted correctly, the whole being surface-soldered. At the

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**Wafios** Spring Coilers.

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## Continuous Wire Drawing Machine

**A light, compact, and inexpensive machine of the ball bearing type, for rapid and economical production of fine wire.**

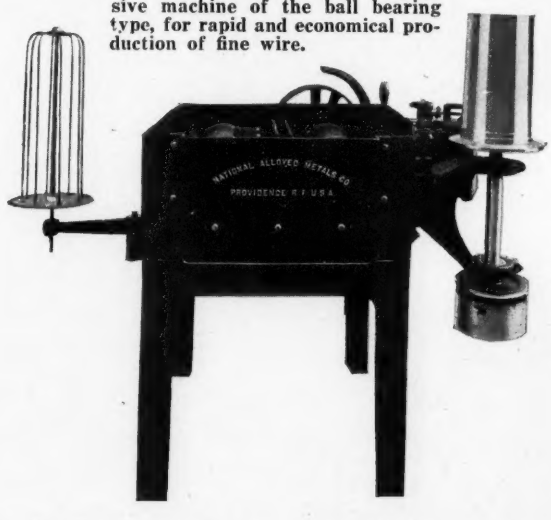



Illustration features No. 2 Machine. Capacity No. 20 B & S to .003.

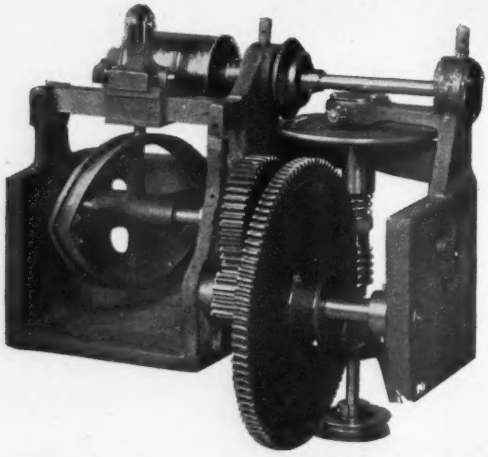
**We will furnish information on other sizes.**

**National Alloyed Metals Co.**

**69 Sprague St.** **Providence, R. I.**

**Spooling Attachment**

Spools wire from .018 to .003 Dimensions 12″x12″x15″
Weight Approximately 50 lbs. Ball bearing equipped



The above illustration shows an open view of our No. 1 Spooler. All gears are enclosed.

Uniform tension and lay of the wire on the Spool is assured by the use of a screw cam. It is inexpensive, simple to operate and can quickly be attached to any machine.

**CYRUS CURRIER & SONS**

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**ROTARY WIRE STRAIGHTENING AND CUTTING MACHINES**

*FULL AUTOMATIC*

Equipped with flying shear allowing uninterrupted feed of wire through the machine.

Guaranteed not to mark or swell wire in spots.

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**HALLDEN MACHINE CO.**

**Thomaston, Conn.**


ends of the tube, as shown in B of Fig. 2, not less than 20 mm. of the length of the tube will be noted as left straight. This is done to prevent tearing down the tube at these ends.

**Bare but Insulated, An Aluminum Wire Contradiction.**

One of the most wonderful of achievements in aluminum has been the production of a bare metal wire which is nevertheless insulated. This result has been produced by subjecting the wire to a certain treatment by which the surface of the wire is insulated, this being a part of the wire so that it can not be peeled. Wound into coils this stands the biggest overloads and strains without injury, usage under which copper coils are very apt to be damaged. The aluminum coils of this wire are equal to those of copper in efficiency and have none of the copper disadvantages.

Engineers have long sought an insulation that would last for a long time without disintegration at high temperatures. These can not be avoided, more especially when the coils are subjected to strong vibrations One critical point has been the humidity. This aluminum self-insulated wire in electrical coils is humidity-proof.

This is important in motors used outdoors by contractors, by builders, in harbors, freight stations, any and all other outdoor work where the motors can not be brought under shelter. The organic matter usually used for copper wire insulation is a good heat retainer, consequently is apt to retard the specific heat generated in the coils by the current flowing through them. Also, each and every layer of such wires causes retardation of heat, being insulated one from another. The net result is that hardly any heat is deflected until the outside or surface layers get warm and this forms the only means of effective heat radiation.

**Square Aluminum Wires Readily Cooled.**

With the aluminum wires, square sections are employed

with no organic insulation, the heat quickly travels to the surface or if enclosed, to the casing. Therefore, there is little heating of the coil, which has a longer life, also less heating of pole shoes and armature points, all of which contribute to longer motor life.

The coefficient of efficiency is higher because with the square section used in aluminum wires the air spaces between windings and layers of round copper wires and which act as heat retainers, are avoided. Organic insulations shrink and become loose through this and vibration. All these factors contribute to expense of operation, of maintenance, and time lost through inspection, repairs, etc.

The aluminum wires need a little increase in diameter to produce the same conductivity, but the total cubic increase in coil size is little because of the space saved by the insulation. Against this, the lighter weight is a big factor. The smaller weight has many advantages in itself. It allows better and easier handling, insures quicker installation, etc. When these coils are used for street car service the saving in weight is considerable, as the following table shows. This means a smaller consumption of current or the ability to carry more passengers, both important to street railway executives these days of decreasing traffic.

In such aluminum coils the ordinary thought is that they should have the same number of windings as copper and because of the larger diameter would not occupy the same casings as copper, but this is not the case. The specific resistances of the two metals at a temperature of 20 deg. C. is in the ratio of 17 (for copper) to 28. Inasmuch as excess temperatures of 70 deg. are allowed by the railway code, it is possible because of aluminum's higher heat coefficient (.23 against .09) to use not only equal sizes but actually smaller diameter or cross sections. The following table presents this and other advantages of aluminum wire and corresponding disadvantages of copper wire in a comparative form.

*Aluminum Coils.*

1. No insulation.
   Indestructible by overload, humidity, impulsion.
2. Constancy of coil volume.
   No retightening of coil. No friction of coil windings against each other. No short circuits.
3. No retardation of heat.
   Longer life of coil. Very little heating of pole shoes and armature with less reduction in efficiency.
4. No air spaces between wires.
   No heat retardation. Best heat deflection. Constant fixed position of turns as well as layers.
5. Much less dead load (60-65% saving).
   Low cost of transportation. Easy quick, cheap installation. Lighter and cheaper tightening elements. Little wear on coil bindings. Less consumption of current per motor (street cars) or larger capacity for transportation.
6. Smaller starting capital.
   Less loss of interest.
7. Better running safety.
   More life shown in practice.

*Copper Coils*

1. Organic insulation.
   Destructible by overload, humidity, impulsion.
2. Shrinkage of coil volume.
   Retightening of coil. Friction of coil windings against each other, producing short circuits.
3. Retardation of heat.
   Destruction of coil. Heating of pole shoes and armature, reducing efficiency.
4. Air spaces between wires.
   Heat retardation. Increased possibilities of friction between layers and turns when coils shrink, with probable short circuits.
5. Considerable dead loss in weight.
   Greater cost of transportation. Troublesome, tedious and expensive installation. Expensive tightening elements. Increased chance to break up insulation material. Larger consumption of current.
6. Larger starting capital.
   Loss of interest. Increased scrap value does not figure until coil is defective.
7. Less running safety.
   Less life shown in actual practice.

This is not experimental but rather a summary of splendid service rendered in Germany, Russia, Switzerland, Hungary, Italy and other European countries dating back as far as 1910. The value of aluminum as a current carrier, leaving aside the bare wire self-insulating method, has been absolutely proven beyond doubt in international

Amsler's Wire Ductility Tester

**The "Usefulness" of Wire in the Manufacture of Wire Products depends in Most Cases upon its "Ductility"**

The best apparatus for investigating the ductility of round and flat wire, ferrous and non-ferrous, is the "Amsler Reversed Bending Tester" illustrated above.

This apparatus gives very valuable information. It can be operated by any intelligent man in the shop and it is inexpensive.

Every wire forming shop should be equipped with this handy, practical wire tester. Some plants are using a number of them in different departments.

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**Complete Line of High Quality Metal Testing Machines.**

**The "Superior" Wire Drawing Machine**

The ultimate in a compact and inexpensive machine.

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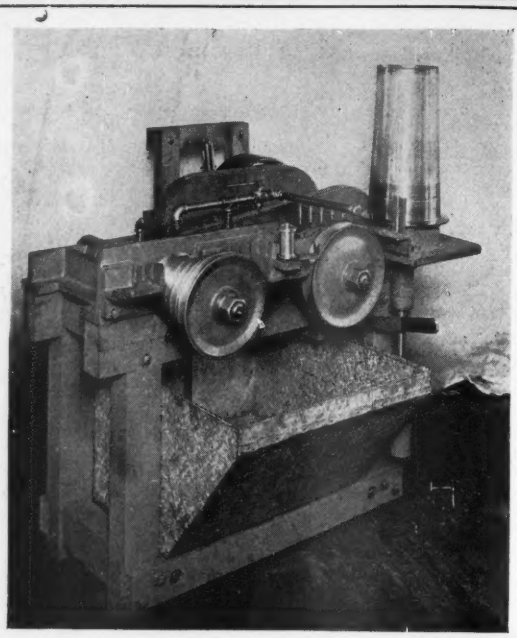

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service, and has had international approval.

There is no doubt that aluminum wire will play a more important part in technical science in the years to come than any other metal. Watching its growth and expansion in the past has brought one surprise after another. From an inside knowledge of many experiments which cannot be mentioned here, it is safe to say many accepted rules will be contradicted.

**No Limit to Aluminum Wire's Future.**

Space prevents going further into details of uses for aluminum wire which have been found one by one, but it will suffice to say that there is scarcely any limit to what may be done with it. Ingenuity in finding new uses and aggressiveness in following up all these new uses will open up many entirely unthought-of fields for this material. Just as the sheets and shapes have found hundreds, perhaps thousands, of new and different uses, so the wire is bound to do.

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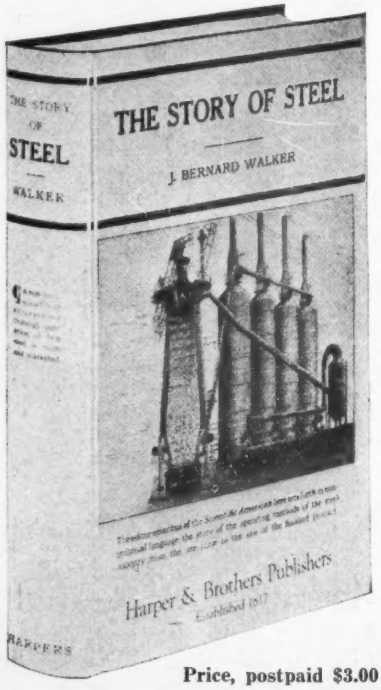


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## Manufacture and Properties of Hair Springs

(*Continued from page 117*)

fer an initially higher elastic limit and hardness. In trials of straight hairsprings of phosphor-bronze containing 6.5 per cent. tin in an escapement giving more than 80 beats per second, much better timing was obtained after the hairsprings had been given a low-temperature heat-treatment of 30 minutes at 200° C. in an oil-bath, the strip being clamped between plane steel faces which allowed expansion and contraction in longitudinal and lateral directions, but prevented bending or other deflection.

Experimental treatment of this strip at 100°, 150°, 200°, 250°, and 300° C. showed that the tensile strength after treatment remained approximately constant at 74 to 75 tons/in.$^2$ until 250° C. was reached; after 300° C. it fell to about 65

tons/in.$^2$ The most suitable temperature for restoration of elasticity appears to be about 200° C.

It is probable that phosphor-bronzes containing 8 to 10 per cent. of tin and not more than 0.2 per cent. of phosphorus would repay investigation, and might prove to be more suitable for some purposes than those of lower tin content. The use of copper-nickel alloys and other nickel alloys for hairsprings might also be considered.

### Palladium Alloys.

The use of palladium alloys for hairsprings appears to be restricted to chronometers. The high cost of this metal would probably prevent its general use in instruments. Its advantages of incorrodibility combined with a high elastic limit are now obtainable in much cheaper materials.

### Alloys of Low Electrical Resistance.

Owing to the incompatibility of low electrical resistance and high elastic limit, it is desirable to avoid as far as possible the necessity for low electrical resistance in hairsprings. It is understood that in some cases in which the current passes through the hairspring, hard-drawn phosphor-bronze containing from 1 to 2 per cent. of tin has been used. Small percentages of cadmium* (up to 2 per cent.) raise the hardness and elastic limit of copper considerably, but raise its electrical resistance to a much smaller extent than the equivalent amounts of any other alloying metal commonly employed. The copper-cadmium alloys are readily drawn into wire, and their use for low-resistance springs appears to be worth considering.

In the case of low-tin bronze (tin not exceeding 2 per cent.), copper-cadmium alloys, and certain other possible alloys, further experimental work is required to determine the most

*W. C. Smith, "Copper-Cadmium Wire for Electrical Transmission," Chem. and Met. Eng., 1921, 25, 1178. N. F. Budgen, "Cadmium" (Griffin). p. 203.


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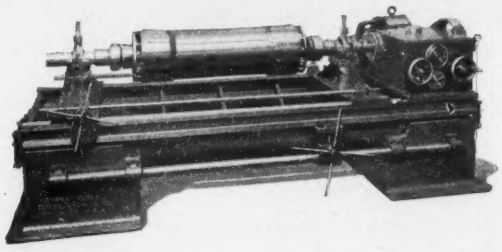

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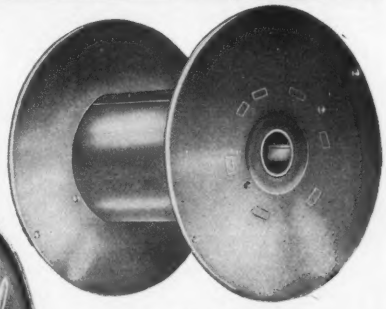

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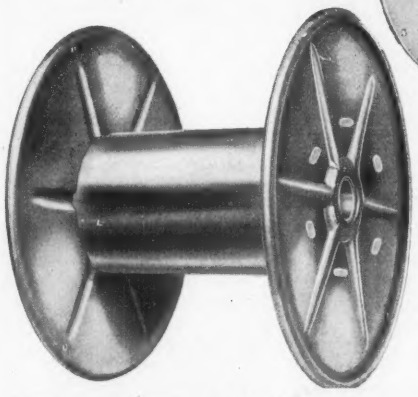

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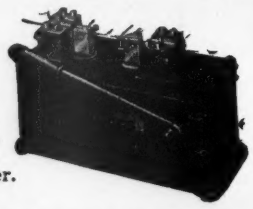

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suitable composition, method of manufacture, and heat-treatment to give serviceable hairsprings.

**Coiled Springs.**

The manufacture of coiled hairsprings usually involves coiling operations after the requisite hardness and elastic properties have been obtained, although steel helical springs for chronometers are commonly coiled to the desired form before hardening and tempering. In the case of non-ferrous springs any coiling required must be done after the strip has been fully hardened by cold-drawing or rolling; this applies equally to cold-drawn steel springs, and sometimes to steel springs hardened by quenching and tempering, if these operations precede coiling. The wire or strip is coiled on mandrels. The size of the mandrel is determined by experiment, since the coil opens out partially when the winding pressure or tension is released. As the amount of springing out depends on the dimensions and properties are necessary to give springs of uniform dimensions.

It has already been pointed out that elasticity is seriously impaired by the permanent deformation involved in coiling. It appears, however, to be fairly general practice to leave a cold-coiled spring in this condition. The imperfect elasticity may result in a decrease in the distance between coils during use, and in alterations in zero readings. The use of low-temperature heat-treatments, after coiling, for preventing such troubles by restoring elasticity, has been indicated above, and has been successfully adopted for phosphor-bronze and other springs.

**The Testing of Hairspring Strip.**

The uniformity of strip, especially cold-worked strip, is most conveniently tested by determining the tensile strength. A simple dead-loading device, in which weights or shot are loaded into a scale pan hung on the strip, has been found con-

venient. Some precautions are necessary, owing to the very small area of cross-section. The grips are carefully radiused on the edges, and the hairspring wire or strip is clamped between smooth steel faces. Twisting of the strip and any form of impact loading must be avoided. In another form of the apparatus the pull is applied by means of a screw through a suitably calibrated spring balance. This type of apparatus eliminates the danger of impact loading, and can be arranged to avoid torsion stresses, a common trouble in the testing of thin strip. In order to obtain true breaking loads on fine wire and strip the pull must be axial, and the specimen under test must be free from kinks.

The Brinell hardness test made with a ball of 0.8 or 1 mm. diameter and a suitable load, which can be readily determined, will give useful indications of the hardness of strip if it is not too thin or narrow. Even if true Brinell hardness numbers are not obtained, useful comparative figures are secured when the conditions governing the tests are carefully standardized.

---

## New Developments in Copper Wire Manufacture

(*Continued from page 131*)

ing solution is pumped from underfloor tanks avoiding all storage or hot compound at the machine. Each head is motor driven and controlled by conveniently located push-buttons. For each pair of heads a roll pointer and die stringer is installed.

The No. 3 machine is designed for finishing the finer sizes from No. 31 B & S to .0025" through 12 dies. From Figure 5 it will be seen that the general design is similar to that of the No. 2 machine. Since a wire pointer and stringer is unnecessary for fine wire it has been possible to group 8 heads in the same space as 4 heads of the intermediate machine, namely

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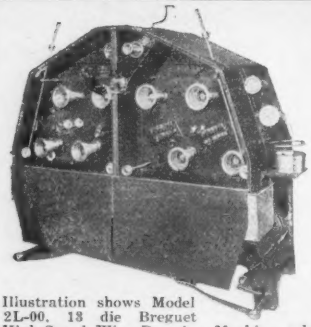

Illustration shows Model 2L-00, 13 die Breguet High-Speed Wire Drawing Machine, which draws No. 36 Brown and Sharpe Gauge and finer sizes of copper wire at a finishing speed of 4000 to 4500 feet per minute.

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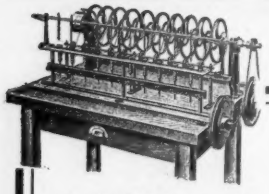

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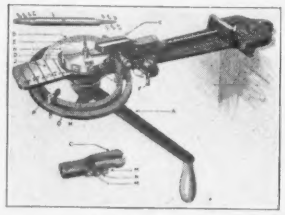

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5'x7'. Owing to the close grouping of heads and the finishing speed of 3000 ft. per minute an extraordinary output of finished wire is obtained from a given floor space. The take-up mechanisms are of the same general design as those of the No. 2 and are built to accommodate both 10 lb. and 5 lb. spools. A single motor drives the entire machine, the individual spindles being controlled through sensitive clutches operated by foot pedals.

These wire drawing machines have now been in successful operation for over three years. In order that others engaged in wire drawing may avail themselves of this modern machinery, the Western Electric Company has granted exclusive licenses under its patents to the Vaughn Machinery Company of Cuyahoga Falls, Ohio, for the manufacture of the Nos. 1, 2 and 3 wire drawing machines.

## Manufacture and Care of Diamond Dies

(*Continued from page 125*)

round when worn to an oval shape, enlarging their diameter; these operations are generally termed re-cutting. These machines are built in various types and sizes, but Figure 5 illustrates the principle of all these types. The re-grinding has been variously attempted by ways of reciprocating wires through the revolving die or by running endless wires through such dies in a coning and lapping operation. But the method embodied in the diagram of Figure 5 is to-day most universally adopted owing to its efficiency in rounding out non-circular dies as well as in coning and lapping.

The die is mounted on a rotating table and is faced by the pinion the end of the spindle which revolves in the opposite direction contrary to the spindle in the previously described apparatus, which were undirectionally mounted in two bearings, these spindles are supported in a swivel-point below the pulley, indicated by a ball shape

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in the sketch—and the supporting bearing at that point is reciprocated transversely along the paths of the dashed line with the arrow-heads at the ends. The spindle takes at the extreme positions the angular location indicated in the sketch to the right. In the center of the reciprocating paths it has the co-axial position shown in the diagram to the left. The upper end of the spindle is supported in a slide. Raising or lowering the revolving die-table and adjustment of the transverse reciprocating motion of the swivel bearing on the spindle offer a complete control of the recutting operation. The salient advantage is the raising and lowering of the pin-point in the hole of the diamond due to the transverse reciprocating motion; this motion automatically takes care of the sharpening of the pin-point, of the feeding of the abrasive material and of the true rounding out of the full length of the hole in the diamond. The reciprocations are as slow as practically convenient. Owing to rotation in opposite directions on the part of die and spindle the abrasive action is very rapid. The machines embrace 10 heads as a standard, and one operator can watch two or three machines.

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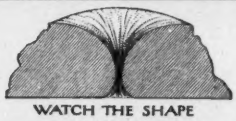

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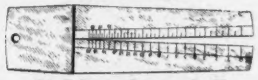

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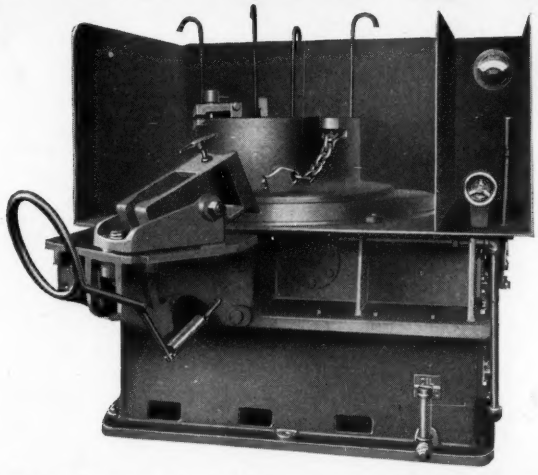

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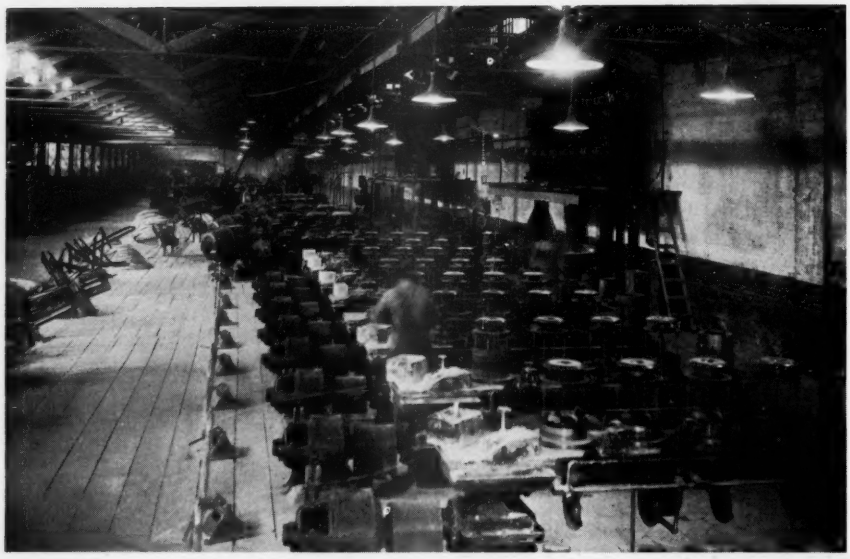

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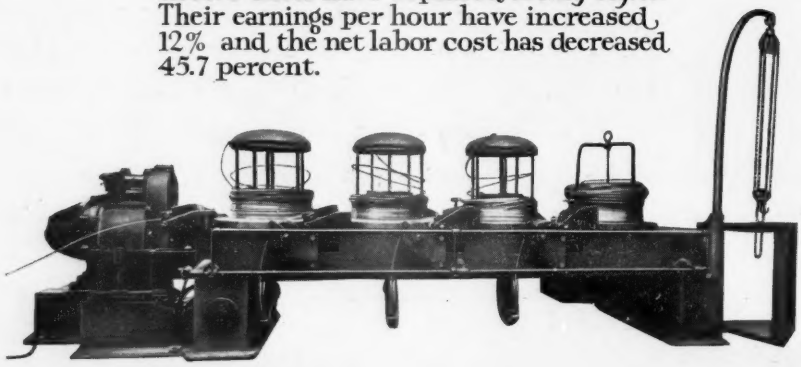

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